RELIABILITY ASSESMENT OF CNC TURNING CENTER BASED ON INDUSTRIAL STATISTICS

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SUPERVISOR DECLARATION

I hereby declare that I have read this report and in my opinion this report is sufficient in term of scope and quality for the award of the degree of Bachelor of Mechanical Engineering with Manufacturing Engineering.

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STUDENT DECLARATION

I declare that this thesis entitled *"Reliability Assesment of CNC Turning Center Based On Industrial Statistics"* is the result of my own research except as cited in the references. The thesis has not been accepted for my degree and is not concurrently candidature of any other degree.

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ABSTRACT

Control charts are basic tools in industrial statistics to statistically assess performance-related parameters of a machine or process. The objective of this project is to evaluate the reliability of the CNC machine in the UMP lab using the concept of quality control, namely $\bar{x}$ and R. In order to develop the control chart, a number of identical round bars will be generated on titanium in different environments. The measured data used for $\bar{x}$ and R are diameter and surface roughness. For machining tests, all of the machining experiments were carried out on ROMI C420 CNC turning machine. The machining parameters are set based on literature. Diameters of the bars are measured with digital micrometer and the surface roughness by using perthometer. A total of 60 data for each bar was collected. In control chart, 20 samples of size 3 were used. The control charts were plotted manually as well as in STATISTICA. It has been found that reliability of the machine tested depends on the control limits defined and tolerable part dimensions.

ABSTRAK

Carta kawalan kualiti ialah cara asas dalam statistik industri untuk menilai prestasi mesin atau proses. Tujuan projek ini adalah untuk menilai kebolehpercayaan mesin CNC di lab UMP dengan menggunakan konsep carta kawalan kualiti, iaitu $\bar{x}$ dan R. Dalam rangka mengahsilkan carta kawalan kualiti, sejumlah bar bulat identik akan dihasilkan pada titanium dalam keadaan persekitaran yang berbeza. Data yang diukur digunakan untuk menghasilkan $\bar{x}$ dan R adalah diameter dan kekasaran permukaan. Untuk ujian mesin, semua eksperimen dilakukan pada mesin CNC Romi C420 berputar. Parameter pemesinan dipersiapkan berdasarkan literatur. Diameter bar diukur dengan mikrometer digital dan kekasaran permukaan dengan menggunakan perthometer. Sebanyak 60 data untuk setiap bar dikumpulkan. Pada carta kawalan, 20 sampel dengan saiz 3 digunakan. Grafik kawalan diplot secara manual maupun di Statistica. Didapati bahawa kebolehpercayaan mesin diuji bergantung pada kawalan batasan yang telah ditentukan dan ukuran bahagian toleransi.

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LIST OF SYMBOLS

mm	Millimeter
µm	Micron meter
σ	Standard Deviation
$\bar{X}$	Mean
μ	Mean of Sample Mean
N	Number of Sample
$\bar{R}$	Mean of range
d	Diameter

LIST OF ABBREVIATIONS

UMP	Universiti Malaysia Pahang
FKM	Fakulti Kejuruteraan Mekanikal
CNC	Computer Numerical Control
UCL	Upper Control Limit
LCL	Lower Control Limit
AHWR	Advanced Heavy Metal Reactor
APSRA	Assesment of Passive System Reliability
FORM	First-Order Reliability Method
SORM	Second-Order Reliability Method
IS	Industrial Statistics

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

Computer numerical controlled (CNC) machines play a major role in the modern machining industry, product qualities as well as productivity become important issues. Therefore, the optimum turning conditions have to be set. Throughout the entire production processes, the product needs to be monitored in order to meet the overall specifications.

In the most general terms, there are two product defects; i.e. are the deviations from target specification and excessive variability around target specifications. During the earlier stages of developing the production process, designed experiments are often used to optimize these two quality characteristics. The term reliability used in industrial statistics denotes a function describing the probability of failure as a function of time. As the marketplace for industrial goods has become more global, manufactures have realized that the quality and reliability of their products must be as high as possible for them to competitive. To cope with other competitors, many machine begun to give importance to the reliability of CNC machine because CNC machine are expensive and complicated.

In this project, quality control chart will be developed using STATISTICA software for CNC turning center to investigate the reliability of the machine. A number of identical geometry bars will be machined on cylindrical titanium in different environment. Diameter of cylindrical bar will be measured by using micrometer and the surface roughness will be measured by using perthometer to verify the accuracy of the machine.

1.2 PROBLEM STATEMENT

The reliability knowledge of a particular process is important to track their performance from time to time and quality control. It is generally recognized that the most cost-effective way to maintain high quality is through constant monitoring of the production process. This monitoring is often done by sampling unit production and measuring some quality characteristic. The reliability record of turning center commonly used in manufacturing process is unknown. Seems the titanium pure is expensive, so it is important to control the quality of the product to reduce defect in the manufacturing industry.

1.3 PROJECT OBJECTIVES

The objectives of this study consist of:

(i) To develop the quality control charts for CNC turning center.

(ii) To evaluate the reliability of CNC turning center based on industrial statistics.

1.4 SCOPE OF PROJECT

The scopes of this project are:

(i) A number of round bars having same diameter will be generated on titanium using CNC turning center in different time frames and environmental condition.

(ii) Surface roughness of turned bars will be measured using perthometer.

(iii) Diameters of the bars will be measured with precision vernier caliper or micrometer.

(iv) Quality control chart will be developed manually as well as by using STATISTICA software to asses reliability of turning center.

1.5 THESIS ORGANIZATION

Chapter 1 introduces the background of the project. The problem statement and the scopes of this study also included in this chapter. Chapter 2 presents the literature study. Chapter 3 discusses the experimental under different experimental conditions, data measurements and analysis. Chapter 4 presents the results and analysis of the obtained results. Chapter 5 presents the conclusion and recommendation of the future work.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The main purpose of this literature review is to get the information from reference books, journals, technical papers and website to complete the project. For this chapter, some information from different sources will be discussed.

2.2 RELIABILITY

Reliability is the ability of a set of device or measuring instrument to consistently perform without failure under given circumstances such as environmental condition (John Davidson, 1994). The reliability of a result pertains to the representative of the result found in a specific sample for the entire population. In other words, it says how probable it is that a similar result would be found if the data collection procedure was replicated with other samples drawn from the same population. A number of specialized techniques in industrial statistics have been developed to quantify reliability. These techniques are all based on statistical analysis (B. S. Dhillon, 2004). The more critical the application of a particular product, the higher its reliability must be (Serope Kalpakjian, et al 2006).

A.K.Nayak, et al 2009, explained about the methodology known as APSRA (Assessment of Passive System Reliability) has been used to evaluated the reliability of isolation condenser system of AHWR (advanced heavy metal reactor).The system failure probability has been identified through fault-tree analysis and it’s found to be

3.703e-07/yr. As per the APSRA methodology, the passive system reliability evaluation is based on the failure probability of the system to perform the design basis function.

N.Mealier, et al 2008, explained about the failure probability of a locking system. This failure probability is assessed using complementary methods: the First-Order Reliability Method (FORM) and Second-Order Reliability Method (SORM) as approximated methods, and Monte Carlo simulations as the reference method. In this work, a reliability approach is developed for analyzing the safety of locking systems. A mechanic reliability engineer method, combining both mechanical and reliable tools, is proposed to assess the failure probability Pf of those systems including uncertainties.

Haita Guo, et al 2008, explained about the wind energy industry, wind farm operators have greater interest in recording wind turbine operating data. However, field failure data may be tainted or incomplete, and therefore it needs a more general mathematical model and algorithms to solve the model. The aim of this paper is to provide a solution to this problem. A three-parameter Weibull failure rate function is discussed for wind turbines and the parameters are estimated by maximum likelihood and least squares. Two populations of German and Danish wind turbines are analyzed. The traditional Weibull failure rate function is also employed for comparison. Analysis shows that the three-parameter Weibull function can obtain more accuracy on reliability growth of wind turbines. This work will be helpful in the understanding of the reliability growth of wind energy systems as wind energy technologies evolving.

Q. Long, et al 2005, explained about further proposes a reliability optimization problem of weighted voting systems under cost constraints. Monte Carlo algorithm is given to analyze the model and evaluate the reliability. A reliability optimization problem with cost constraints is then formulated.

2.3 QUALITY CONTROL

Quality Control describes numerous methods for monitoring the quality of a production process. However, once a process is under control the question arises, "to what extent does the long-term performance of the processes comply with engineering requirements". The methods provided in Quality Control are on-line or in-process quality control procedures to monitor an on-going production process. Even though one could arbitrarily determine when to declare a process out of control it is common practice to apply statistical principles to do so.

One of the early pioneers in the area of statistical quality was Dr. Walter A.Shewart of the Bell Telephone Laboratories. In 1924, he developed the modern control chart, which remains one of the most widely used tools for quality control to this day. After World War II, W. Edwards Deming was instrumental in simulating interest in quality control. The Japanese scientist Genichi Taguchi played a major role as well, developing methods of experimental design with a view toward improving quality (W. Navidi, 2008).

2.4 TURNING MACHINE

Turning center or lathe is very common process found in manufacturing industry which is spins the workpiece to perform various operations such as cutting, sanding, knurling, drilling, or deformation with tools that are applied to the workpiece to create an object which has symmetry about an axis of rotation. There are a number of other lathe machine types such as bench lathes, special-purpose lathes, tracer lathes, automatic lathes, automatic lathes and computer-controlled lathes. The dimensional accuracy and surface finish obtained in turning and related operations depend on several factors such as the characteristics and condition of the machine tool, stiffness, vibration and chatter, process parameters, tool geometry and wear, the use of cutting fluids, the machine ability of the workpiece material, and operator skill. Vibration during cutting can cause poor surface finish, poor dimensional accuracy, excessive tool wear and premature failure (Serope Kalpakjian, et al 2006). The precision of CNC or NC machine is defined by is resolution. The resolution of this machine is typically 0.001 mm. This precision is depend on the machine part which is the spindle, hydraulic and the workpiece clamping,

Yiqiang Wang, et al 2001, explained about an effective reliability method is needed to allocate system level reliability requirements into subsystem and component levels. A comprehensive method is proposed in this paper for allocating the required system reliability level into each subsystem. Actions should be taken to improve the reliabilities of this subsystem such as turret, clamping accessory and so on.

2.5 TITANIUM

Matthew J. Donaiche explained about the titanium that was discovered in 1790 but purified until the early 1990s. Moreover, the metal did not become widely used until the second half of the twentieth century. However, titanium now has the accumulated experience of some 50 years of modern industrial practice and design application to support its use. Much of this use has come in military application in aircraft or gas turbine engine. More recent used have featured such items as golf clubs and bicycles. Titanium has found its niche in many industries, owing to its unique density, corrosion resistance and relative strength advantages over competing materials such as aluminium, steels and superalloys. Some significant facts and/or important benefits offered by titanium alloys illustrate the basis for the widespread use of titanium today. The density of titanium is only 60% of that of steel or nickel-base superalloys. The tensile strength of titanium can be comparable to that of lower-strength martensitic stainless and is better than that of austenitic or ferritic stainless. Alloys can have ultimate strength comparable to iron-base superalloys, such as A286, or cobalt-base alloys, such as L605. The commercial alloys of titanium are useful at temperatures to about 538ºC to 595ºC, dependent on composition. Some alloys systems may have useful strengths above this temperature. The cost of titanium, while approximately four times that of stainless steel, is comparable to that of superalloys. Titanium is exceptionally corrosion resistant. It often exceeds the resistant of stainless steel in most environments and it has outstanding corrosion resistance in the human body.

Shane Y. Hong, et al 2001, explained about titanium and its alloys are classified as difficult-to-machine materials. The main problems in machining them are the high cutting temperatures and the rapid tool wear. Most tool materials wear rapidly even at moderate cutting speeds. To minimize tool wear, current machining practice limits the cutting speed to less than 1 m/s. The machining characteristics for titanium and its alloys are summarized as followed.

Firstly, titanium and its alloys are poor thermal conductors. As a result, the heat generated when machining titanium cannot dissipate quickly; rather, most of the heat is concentrated on the cutting edge and tool face. Secondly, titanium has a strong alloying tendency or chemical reactivity with the cutting tool material at tool operation temperatures. This causes galling, welding, and smearing, along with rapid wear or cutting tool failure. Thirdly, during machining, titanium alloys exhibit thermal plastic instability which leads to unique characteristics of chip formation. The shear strains in the chip are not uniform; rather, they are localized in a narrow band that forms serrated chips. Fourth, the contact length between the chip and the tool is extremely short (less than one-third the contact length of steel with the same feedrate and depth of cut). This implies that the high cutting temperature and the high stress are simultaneously concentrated near the cutting edge (within 0.5 mm). Lastly, serrated chips create fluctuations in the cutting force; this situation is further promoted when alpha–beta alloys are machined. The vibrational force, together with the high temperature, exerts a micro-fatigue loading on the cutting tool, which is believed to be partially responsible for severe flank wear.

Titanium and its alloys represent the most challenging materials in machining. With advances in cutting tool materials, many difficult-to-machine materials can now be machined at higher metal removal rates. None of these tool materials, however, seems to be effective in machining titanium because of their chemical affinities with titanium. New development in tool coating also does not help titanium machining. Al2O3 coating has a lower thermal conductivity than the tungsten carbide insert, which prevents heat dissipation from extremely concentrated high stress and high temperature at the cutting point. Titanium carbide and titanium nitride coatings are not suitable for machining titanium alloys because of their chemical affinities. Thus, cryogenic machining, which is able to both lower the cutting temperature and enhance chemical stability of the workpiece and the tool, is expected to greatly increase productivity level in the machining of titanium and its alloys.

2.6 MEASUREMENT TOOL

In this project, two types of instruments which is micrometer and perthometer were used to obtain the diameter and surface roughness of the sample in order to finish the project.

2.6.1 Micrometer

Francis T. Farago, et al 1994, explained that a few decade ago micrometer were considered he ultimate in precision for length measurements. Even the measuring machines used at those times in gage laboratories operated on the principles of micrometer. More sensitive measuring instruments were developed to satisfy the accuracy for higher accuracy and they replaced the use of micrometers in many application. Most of the higher sensitivity instruments, however, are of the comparator type, which require setting masters for referencing, possess only a reduced measuring range and are, to some extent, generally stationary. These, and many other characteristics, are definite disadvantages in comparison to the portable micrometer, with its capability of measuring actual lengths by direct indication over a substantial measuring range. In addition, to these inherent advantages of the micrometer system and the relatively low price of measurements, many recent improvements in the design and manufacture of micrometer gages contribute to assuring continuing important role to this category of measuring tools in the field of length measurements.

2.6.2 Perthometer

Boubekri N explained that, instrument called Perthometer are used to measure and record surface roughness. In Perthometer, the stylus is loaded on the surface to be measured and then moved across the surface at a constant velocity to obtain surface height variation. Perthometer is characterized by a multitude of functions. After carrying out a measurement, periodic and non-periodic profiles can be identified and the cutoff set according to standards automatically, such that unintentional non-standard measurements are excluded.

Serope Kalpakjian, et al 2006 explained that the distance that the stylus travels is called the cutoff, which generally ranges from 1.75 mm to 17.5mm. The rule of thumb is that the cutoff must be large enough to include 1 to 5 roughness irregularities, as well as all surface waviness. In order to highlight the roughness, the Perthometer M1 traces are recorded on an exaggerated vertical scale that is a few order of magnitude larger then horizontal scale. The magnitude of the scale is called gain on the recording instrument. Thus the recorded profile is distorted significantly, and the surface appears to be much rougher than it actual is. The recording instrument compensates for any surface waviness. The smaller stylus diameter and the smoother surface, the closer is the path of the stylus to the actual surface profile.

2.7 STATISTICS

Jay Devore, et al 2005 explained that, statistics is widely employed in government, business, and the natural and social sciences. Statistics is the science of making effective use of numerical data relating to groups of individuals or experiments. It deals with all aspects of this, including not only the collection, analysis and interpretation of such data, but also the planning of the collection of data, in terms of the design of surveys and experiments. A statistician is someone who is particularly versed in the ways of thinking necessary for the successful application of statistical analysis. Often such people have gained this experience after starting work in any of a list of fields of application of statistics

There is also a discipline called mathematical statistics, which is concerned with the theoretical basis of the subject. Statisticians improve the quality of data with the design of experiments and survey sampling. Statistics also provides tools for prediction and forecasting using data and statistical models. Statistics is applicable to a wide variety of academic disciplines, including natural and social sciences, government, and business